## REMARKS

This Amendment and Response is responsive to the Final Office Action mailed June 3, 2005. In that Action: claims 1-26 were pending; claim 25 was rejected under 35 USC 112, first paragraph, as failing to comply with the enablement requirement; claims 1, 3-10, 14, 16-24, and 26 were rejected under 35 USC §103(a) as being unpatentable over Liu, et al. (USPN 6,141,076); claims 2, 12, and 15 were rejected under 35 USC §103(a) as being unpatentable over Liu in view of Iwayama (USPN 5,323,253); claim 11 was objected to as being dependent on a rejected base claim; and claim 13 was allowed. Reconsideration of the rejected claims is hereby requested.

The examiner rejects claim 25, stating that it contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and /or use the invention. Apparently it is the limitation "wherein the ferroelectric liquid crystal material in the optical device is surface stabilized" that the examiner feels a skilled practitioner would have difficulty with.

In fact, the term "surface stabilized" is widely used in the ferroelectric liquid crystal art. It has been used at least since 1984, as evidenced by the attached page from a paper by Noel A. Clark and Sven T. Lagerwall entitled "Surface-Stabilized Ferroelectric Liquid Crystal Electro-optics: New Multistate Structures and Devices," published in Ferroelectrics vol. 59, pp. 25-67 (1984). It is also found in handbooks on the subject, as evidenced by the attached page from a chapter entitled "Electric Field Effects in Liquid Crystals," by L.M. Blinov in the *Handbook of*

*Liquid Crystal Research* edited by Peter J. Collings and Jay S. Patel (Oxford University Press, Oxford, 1997).

From both these examples, it is clear that this term means exactly the same as the phrase in applicant's specification -- an FLC device that is sufficiently thin enough to prevent helical rotation of the director of each FLC molecule through the smectic layers (patent application at Figure 1B; page 1, lines 7-25; and page 5, lines 15-16).

The same terminology is widely used in U.S. patents. When searching the US patent data base, applicant finds 251 instances of patents that contain "surface stabilized" in conjunction with FLC.

We submit that the invention we claim in claim 25 is fully enabled by the above language in the specification.

Claims 1, 3-10, 14, 16-24 and 26 have been rejected as obvious over Liu. The Examiner misrepresents what is disclosed by Liu. Liu discloses that, in a ferroelectric liquid crystal spatial light modulator, one can reduce or eliminate multi-domain texture by applying a treatment of strong cross-buffing. Further, Liu disclosed that this provides for high contrast in the displayed image (col. 4, lines 46-55). Liu never states or even implies that a structure created in this manner is free from chevrons. Nor is it necessarily inherent that Liu's structure would be free of Chevrons. "High contrast" is an undefined, relative term. All it should be taken to mean is contrast relatively higher than some other level of contrast. Certainly it is possible to create a structure with relatively higher contrast than another structure without making the structure free from chevrons.

On the other hand, independent claims 1, 14, 25 and 26 claim an optical device (or, in the case of claim 14, a method for preventing formation of chevron structures in the optical device)

that is free of chevron structures. Since this limitation is not found in or inherent in Liu, these claims are patentable, as are each of the claims that depend thereon.

Claims 2, 12, and 15 have been rejected as obvious over the combination of Liu and Iwayama. Since independent claims 1 and 14 are patentable over Liu, these dependent claims are patentable as well.

Based upon the foregoing, Applicants believe that all pending claims are in condition for allowance and such disposition is respectfully requested. In the event that a telephone conversation would further prosecution and/or expedite allowance, the Examiner is invited to contact the undersigned.

Respectfully submitted,

MARSH FISCHMANN & BREYFOGLE LLP

By: ____________________

Robert G. Crouch
Registration No. 34,806
3151 South Vaughn Way, Suite 411
Aurora, Colorado 80014
(720) 562-5506

Date: August 3, 2005

Ferroelectrics, 1984, Vol. 59, pp. 25–67
0015-0193/84/5901-0025/$18.50/0



# SURFACE-STABILIZED FERROELECTRIC LIQUID CRYSTAL ELECTRO-OPTICS: NEW MULTISTATE STRUCTURES AND DEVICES

NOEL A. CLARK

*Condensed Matter Laboratory, Department of Physics, University of Colorado, Boulder, Colorado 80309*

and

SVEN T. LAGERWALL

*Department of Physics, Chalmers University of Technology, S-41296 Goteborg, Sweden*

(*Received March 13, 1984*)

## TABLE OF CONTENTS

We describe a variety of new electro-optic effects and devices which can be made using the surface-stabilized-ferroelectric-liquid-crystal (SSFLC) geometry. These devices are made possible by application of surface interactions and bulk liquid crystal conditions, recently discovered in SSFLCs, including non-planar boundary conditions, POLAR boundary conditions, boundaries with multiple physical states, intrinsic spontaneous polarization splay, and layers tilted relative to the bounding plates. Using these alone or in combination produces an extensive collection of possible SSFLC structures with monostable, bistable, or multistable states. Such DEVICE STRUCTURES are categorized by a scheme based on structural symmetry and the specific conditions used. Particular device applications of structures employing two, three, and four state devices to nonemissive displays, color displays, and light valves are discussed.

## I. INTRODUCTION

### *A. Previous Work*

In earlier papers[1,2] we have described a liquid crystal electro-optic device employing tilted chiral smectic ferroelectric liquid crystals (FLCs). In that device the liquid crystal is disposed between parallel plates with the planar smectic layers normal to their surface. The plates are treated so that the molecules near the plate surface would adopt an orientation having the average molecular long axis direction parallel to the surface plane. That is, the molecular director, $\hat{n}$, is constrained at the surface to lie in the surface plane. This condition, when combined with the additional constraint that the director make the angle, $\Psi_0$, with the normal to the layers, leads to a geometry in which, if the plates are sufficiently close together, the intrinsic helical configuration of $\hat{n}$ which is present in the bulk will be suppressed, leaving two surface stabilized states of the molecular orientation configuration, each having the ferroelectric polarization normal to the plates but in opposite directions (see Figure 1, Reference 1, 2, or 5 for this geometry). We will refer to devices such as this, which employ surface interactions to stably unwind the spontaneous ferroelectric helix, as surface- stabilized-ferroelectric-liquid-crystal (SSFLC) devices.

The original SSFLC device exhibits several novel features which make it attractive in electro-optic applications and which distinguish it from other liquid crystal devices: (1) Optic axis rotation about the sample normal—A ferroelectric smectic in this geometry behaves optically as a biaxial slab with the optic axes nearly along the director orientation. The biaxiality is generally weak, so the behavior is essentially uniaxial with the uniaxis along the director. The effect of switching is to rotate the uniaxis about the normal to the surface through an angle of twice the tilt angle $\Psi_0$. This is the only liquid crystal parallel-plate geometry allowing a rotation of the uniaxis of a homogeneous sample about the surface normal. (2) *Strong–weak*

# Handbook of Liquid Crystal Research

PETER J. COLLINGS and JAY S. PATEL
Editors in Chief

OXFORD UNIVERSITY PRESS
New York Oxford
1997

To Diane and Susan

OXFORD UNIVERSITY PRESS

Oxford New York
Athens Auckland Bangkok Bogotá
Bombay Buenos Aires Calcutta Cape Town
Dar es Salaam Delhi Florence Hong Kong Istanbul
Karachi Kuala Lumpur Madras Madrid Melbourne
Mexico City Nairobi Paris Singapore
Taipei Tokyo Toronto

and associated companies in
Berlin Ibadan



Published by Oxford University Press, Inc.,
198 Madison Avenue, New York, New York 10016



Library of Congress Cataloging-in-Publication Data

Handbook of Liquid Crystal Research / Peter J. Collings and
Jay S. Patel, editors in chief.
p. cm.
Includes bibliographical references and index.
ISBN 0-19-508442-X
(hardcover : alk. paper)
1. Liquid Crystals. I. Collings, Peter J., 1947- .
II. Patel, Jay S.
QD923.H36 1997
530.4'29—dc20 96-31118 CIP

Printing (last digit): 9 8 7 6 5 4 3 2 1

Printed in the United States of America
on acid-free paper

# CONTENTS

coercivity loop $\Delta V$ in the voltage dependence of the polarization

$$W_d = (1/8)\Delta V P_S \qquad (5.102)$$

and (ii) by measuring the free relaxation times $\tau_d$ to the bistable states for the FLC director:

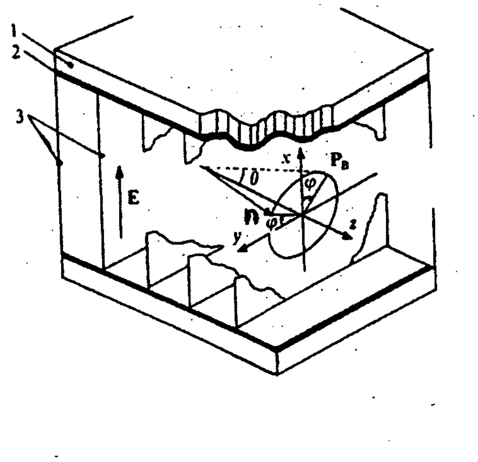
$$W_d = \gamma_\varphi d / 4\tau_d \qquad (5.103)$$

where $\gamma_\varphi$ is the viscosity for the $\varphi$ relaxation of the director.

### 5.5.2.2 The Clark–Lagerwall Effect

Let us consider the best known electrooptical phenomenon in FLCs, the Clark–Lagerwall effect, which results in the director reorientation from one bistable state to another, when the external electric field changes its sign [12] (FIGURE 5.39). In this case, smectic layers are perpendicular to the substrates and the director moves along the surface of a cone, whose axis is normal to the layers and parallel to the cell substrates. In each final position of its deviation, the director remains parallel to the substrates, thus transforming a cell into a uniaxial phase plate. The origin of switching the director is an interaction of the polarization **P** perpendicular to the director with the electric field **E**. The maximum variation of the transmitted intensity is achieved when an FLC cell is placed between crossed polarizers, so that an axis of the input polarizer coincides with one of the final director positions. The total angle of switching equals twice the tilt angle $\theta$. The Clark–Lagerwall effect is observed in the so-called surface stabilized FLC structures (SSFLC) [12,226,227]. In SSFLC cells, $d \ll h$ and the helix is unwound by the walls.

FIGURE 5.39. An FLC cell with the smectic layers (3) perpendicular to the substrates (1) and current conducting layers (2). **E** – electric field, **n** – director.




The variation of the azimuthal director angle $\varphi$ in the Clark–Lagerwall effect is described by the equation for the torque equilibrium, which follows from minimization of the free energy (5.101):

$$\gamma_\varphi \frac{\partial \varphi}{\partial t} + K \frac{\partial^2 \varphi}{\partial x^2} = P_S E \sin\varphi + \frac{\Delta\varepsilon E^2}{4\pi} \sin\varphi \cos\varphi \qquad (5.104)$$

assuming the FLC to be uniaxial, $\Delta\varepsilon = (\varepsilon_{\parallel} - \varepsilon_{\perp}) \sin^2\theta$, and $K$ is a combination of $K_1$, $K_2$, and $K_3$ from (5.97). When the helix is unwound by the cell walls, the second term in the left part vanishes.

The boundary conditions are:

$$K \frac{\partial \varphi}{\partial x} + W_p \sin\varphi \pm W_d \sin 2\varphi |_{x=d,0}. \qquad (5.105)$$

For polarizations $P_S > 10\,\mathrm{nC\,cm^{-2}}$, driving fields $E < 10\,\mathrm{V\,\mu m^{-1}}$ and dielectric anisotropy $|\Delta\varepsilon| < 1$, we have

$$|\Delta\varepsilon E / 4\pi| \ll P \qquad (5.106)$$

and, consequently, the second term in the right-hand part of (5.104) may be omitted. In this case the response times in the Clark–Lagerwall effect are given by

$$\tau_\varphi = \gamma_\varphi / P_S E. \qquad (5.107)$$

If inequality (5.106) is invalid, which occurs for sufficiently high fields, $|\Delta\varepsilon E/4\pi| \simeq P_S$, the response times of the Clark–Lagerwall effect sharply increase for positive $\Delta\varepsilon$ values. In contrast, for negative values of $\Delta\varepsilon$, the corresponding switching times become shorter [228,229]. This is especially important for practical applications because it promotes an increase in the information capacity of FLC displays. For $|\Delta\varepsilon E/4\pi| \gg P_S$, the FLC switching times $\tau$ are approximately governed by the field squared, $\tau \simeq 4\pi\gamma_\varphi/\Delta\varepsilon E^2$, as in the Frederiks effect in nematics.

Reference [230] shows that two regimes of switching exist in the Clark–Lagerwall effect, separated by threshold field $E_{th}$:

$$E_{th} \cong 4 W_d / P_S d. \qquad (5.108)$$

For $E < E_{th}$, one observes the motion of domain walls, separating the regions of differently oriented polarization **P** and $-$**P**. The switching time is defined by the motion of the walls. If $E > E_{th}$ (the Clark–